Incraesed Accuracy in Gear Metrology by using a LaserTracer

The new procedure

By integration of a high-precision tracking laser interferometer (LaserTracer) into a co-ordinate measuring machine, the measuring accuracy of many three-dimensional measurement tasks can be considerably increased (Figure 1).

The LaserTracer is the essential component which allows the measuring accuracy to be increased and high-precision distance measurements between two points in space to be performed. During the measurement, the laser beam of the LaserTracer follows a reflector arranged on the CMM's probing system. The Cartesian co-ordinates of the CMM and the length information of the LaserTracer are combined and evaluated in accordance with a patented procedure.

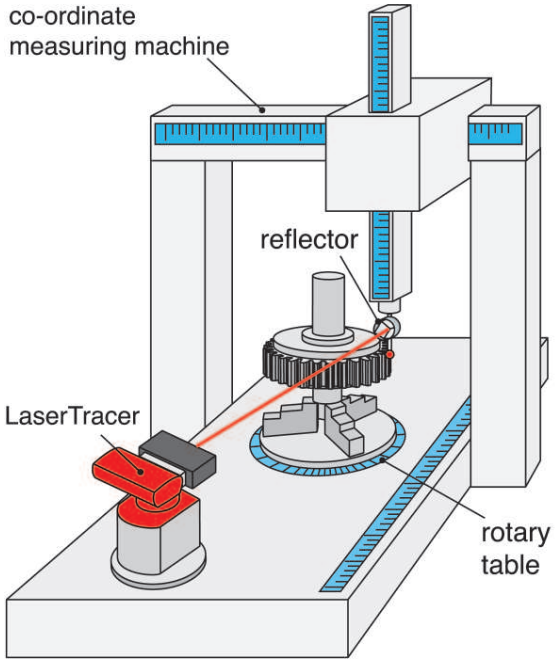
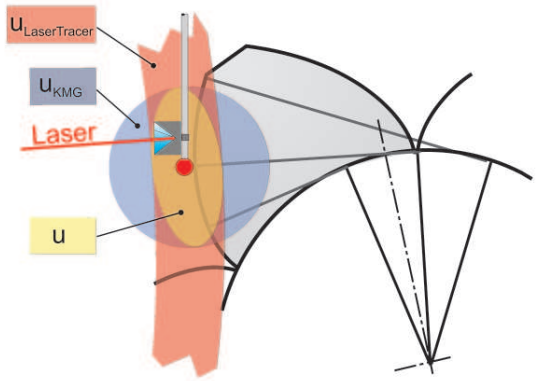


Figure 1: Measuring set-up with the essential components

Principle of accuracy increase

In Figure 2, the principle of accuracy increase is illustrated by the example of a measurement on a gear profile. When the information of CMM and LaserTracer is combined, a measurement uncertainty in the form of an ellipsoid is obtained. Suitably arrangement of the LaserTracer allows the tasks-specific uncertainty of a CMM measurement to be reduced. In the direction of the laser beam it becomes minimal. The achievable accuracy increase depends on the accuracy of the LaserTracer.

The length measurement of the LaserTracer is made use of for online improvement of CMM measurement points. This is achieved by mathematical optimization in the case of which the length information of the LaserTracer becomes more important than the co-ordinates of the measurement points of the CMM.



$u_{LaserTracer}$ measurement uncertainty of the LaserTracer
u_{CMM} measurement uncertainty of the CMM ($u_{CMM} > u_{LaserTracer}$)
u measurement uncertainty based on the new method

Figure 2: Reduction of the measurement uncertainty by the example of a gear profile

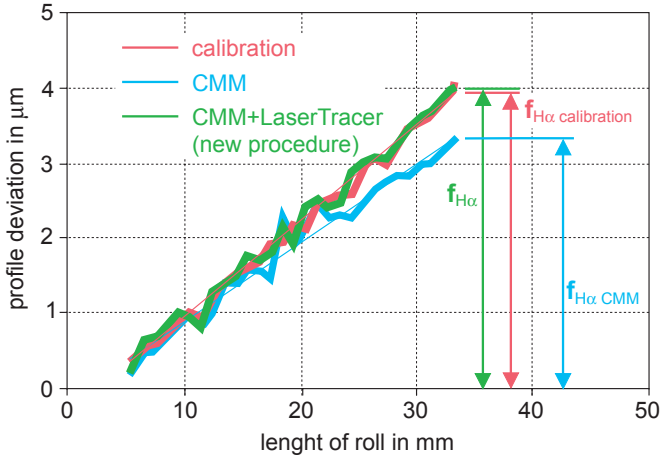
Verification

Comparison measurements performed, for example, on gear standards (diagram) clearly show the reduction of systematic deviations of the CMM when the new procedure is applied.

The new procedure offers the possibility of coming up in future to the constantly increasing accuracy requirements industrial metrology will have to meet in many fields.

Possible fields of application are:

- Form measurements
- Length measurements on 1D to 3D artefacts
- Gear measurements, bevel gear measurements
- Thread measurements etc.



$f_{H\alpha\ calibration}$ calibrated profile slope deviation
$f_{H\alpha\ CMM}$ profile slope deviation measured by CMM
$f_{H\alpha}$ profile slope deviation measured according to the new procedure

Diagram: Comparison of the measurement results for the profile slope deviation

Principle of the LaserTracer

The LaserTracer allows high-precision length measurements to be carried out in space. It is composed of a laser interferometer and a tracking unit. A mechanically decoupled stationary steel precision sphere serves as optical and mechanical reference of the system. Firstly, the laser beam is reflected at its surface before it leaves the interferometer, secondly the interferometer is turned about the centre of this sphere by means of the tracking unit. At the same time, the laser beam automatically follows a reflector moved in space. The driving control is performed via a 4-quadrant diode arranged in the interferometer. Due to the metrological reference to the steel sphere, only the effective distance changes between sphere and reflector are measured, while the relative displacements of the interferometer along the measuring beam do not influence the measurement result.

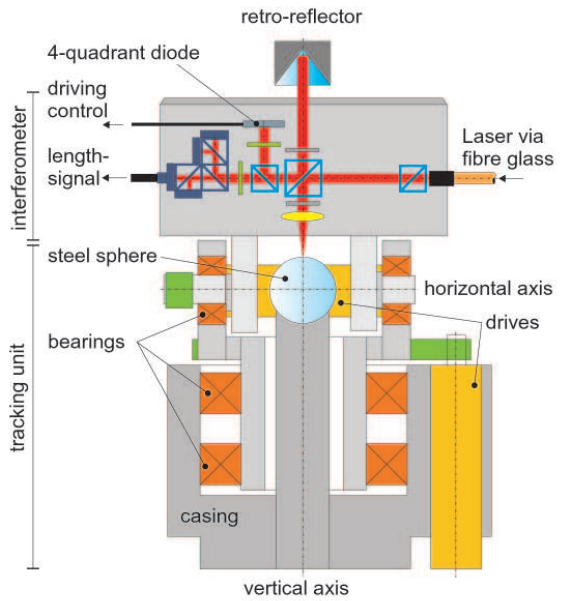


Figure 3: LaserTracer for high-precision length measurements in space

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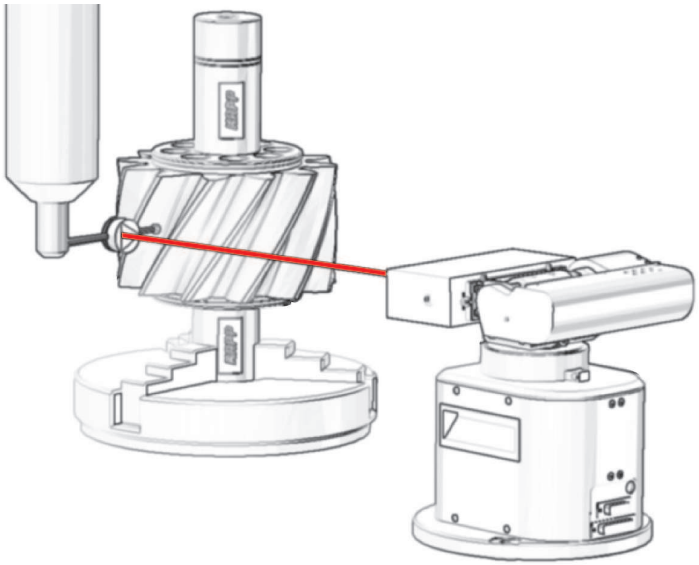

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